Causal Agents of Powdery Mildew of Cucurbits in Sudan

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ABSTRACT

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In a survey of cucurbit crops in Sudan, 234 samples of melon, cucumber, and squash showing symptoms of powdery mildew were infected with *Sphaerotheca fuliginea,* while *Erysiphe cichoracearum* was only observed on two samples of watermelon showing mild symptoms. *Leveillula taurica* was not observed on any sample. Field trials with differential lines of melon revealed the presence of race 1 of *S. fuliginea* in Gezira (Central Sudan) in the summer of 1993, and race 2 in the following winter. Virulence tests in controlled conditions on a limited number of isolates suggest that a shift in prevalence of those races may have occurred on that site over time. The geographic scale of this shift was probably limited as race 0 was observed in late autumn in northeast Sudan in the Gash Delta.

Powdery mildew is one of the most important diseases of cucurbits in Sudan. It causes particularly severe damage to melon (*Cucumis melo* L.), an economically important crop, but also to snake cucumber (*C. melo* var. *flexosus* Naudin), squash (*Cucurbita pepo* L.) and pumpkin (*Cucurbita moschata* (Duchesne) Duchesne ex Poir. and *C. maxima* Duchesne). Among fungi known to cause powdery mildew on cucurbits in other parts of the world, the two causal agents of the disease usually reported are *Erysiphe cichoracearum* DC. and *Sphaerotheca fuliginea* (Schlechtend.:Fr.) Pollaci (4). *Leveillula taurica* (Lév.) G. Arnaud has been reported occasionally on cucurbits (3). It is important to know which species is responsible for the disease in a particular region because *E. cichoracearum* and *S. fuliginea* are known to differ in their virulence to varieties of cucurbits and in their sensitivity to a number of fungicides (3,7). The present study was initiated to identify the causal agents of powdery mildew fungi on cucurbits in Sudan and to determine which physiological races may be prevalent on melon.

MATERIALS AND METHODS

Two hundred and thirty-six samples of melon, cucumber, squash, and watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) showing symptoms of powdery mildew were collected from fields in eastern (Kassala region), central (Gezira region), and western (Kordofan region) Sudan. The isolates were identified in the laboratory based on morphology of conidiophores and conidia (size and shape, presence of fibrosin bodies, types of germ tubes produced) as described by Zaracovitis (14) and Ballantyne (1).

To distinguish physiological races of *S. fuliginea* and *E. cichoracearum* on melon in the field, differential genotypes were planted and exposed to naturally occurring inoculum in three separate experiments in 1993. These melon lines, selected based on data available in the literature (Table 1), provided a unique spectrum of interaction phenotypes for each of races 1, 2, and 3 of *S. fuliginea* and for race 1 of *E. cichoracearum* .

Two field trials were conducted in Gezira in Central Sudan, one planted in June 1993 ("summer trial") and the other in November ("winter trial"). Another trial was planted in the Gash Delta (approximately 600 km east of Gezira) in September 1993 ("late autumn trial"). Melon varieties were grown in 2 × 7 meter plots (2 × 10 meters in the Gash Delta). In each plot, plants were sown 50 cm apart in two rows. A complete randomized design was used, with two replicated plots per variety. The crops were grown according to conventional local practices. Prior to sowing, plots were disk-plowed and harrowed, and nitrogen fertilizer was applied once at a rate of 42 kg nitrogen per hectare. No pesticides were applied and weeding was done by hand. Disease severity was rated for each plot toward the end of each growing season (approximately 3 mo after sowing) on a scale from 0 (no symptoms) to 9 (entire canopy covered with heavy sporulation) with intermediate scores: 3 = few isolated colonies in the canopy; 5 = less than 50% of plants show disease, weak sporulation; and 7 = mild sporulation on more than 50% plants. Varieties with scores 0–3 were classified as resistant. Those with scores above 3 were considered to be susceptible. Samples from diseased plots were taken to the laboratory and the identity of the fungus to species level was determined as indicated above. Local cultigens of melon were included in the summer trial in Gezira to assess their resistance to prevalent strains of powdery mildew.

Four samples of mildewed melon leaves were collected in the winter experiment in Gezira and sent to the INRA laboratory in Montfavet, France, for precise race identification under controlled conditions. Diseased leaves from three squash plants in adjacent plots were included for comparison. The powdery mildew fungus was isolated from each sample and single-spore isolates were grown under axenic conditions on surface-disinfested melon cotyledons maintained in petri dishes on mannitol-sucrose agar (20 g/L mannitol, 10 g/L sucrose, 7 g/L agar, 25 mg/L tetracycline hydrochloride) as described by Bertrand (2,3). Each isolate of *S. fuliginea* was then tested for virulence on five race-differential melon lines in a leaf disk assay as described by Epinat et al (7). For each

Table 1. Interaction phenotypes of differential melon lines that allow distinction between physiological races of *Sphaerotheca fuliginea* and *Erysiphe cichoracearum*

	Sphaerotheca fuliginea					*Erysiphe cichoracearum*	
Melon line	Race 0	Race 1	Race 2[a] "Europe"	Race 2[a] "USA"	Race 3	Race 0	Race 1
Iran H	S[b] (3)	S (3)	S (3)	ND	ND	S (3)	S (3)
Védrantais	R (3)	S (3)	S (3)	S (8)	S (8)	R (3)	S (3)
PMR 45	R (3)	R (7)	S (7)	S (8)	S (8)	R (3)	S (7)
PI 414723	R (3)	R (3)	R (3)	S (8)	ND	R (3)	R (3)
PMR 5	R (3)	R (7)	R (7)	R (12)	S (12)	R (3)	R (7)
Nantais oblong	R (3)	S (7)	S (7)	ND	ND	R (3)	R (7)
Edisto 47	R (3)	R (3)	R (3)	S (12)	R (12)	R (3)	S (3)

[a]See reference 8 for more details and a historical perspective on this denomination.
[b]Numbers in parentheses refer to most recent literature citation where information was found. S = susceptible; R = resistant; ND = no data available.

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isolate and melon line, spores were blown in an inoculation tower onto eight 1.5-cm-diameter leaf disks taken from 6-wk-old plants grown in a powdery mildew-free environment. Inoculated leaf disks were placed on filter paper soaked with a solution of benzimidazole (30 mg/L) and mannitol (10 g/L) to delay senescence of the plant tissue (7), and incubated in plastic boxes in a growth chamber. The temperature in the chamber was 24 C during 12 hr of light (approximately 100 $\mu mol/s/m^2$) and 18 C during the dark cycle. Symptoms were rated individually for each leaf disk at 10 days after inoculation and were classified into 10 categories from 0 to 9 (0 = no detectable fungal growth; 1 = isolated colonies covered less than 10% of the disk surface; 3 = less than 50% of the disk surface covered by weak sporulation; 5 = between 50 and 80% of the disk surface covered by sporulation; 7 = entire disk covered with weak sporulation; and 9 = entire disk covered with heavy sporulation). When classification was difficult, intermediate values were used.

RESULTS

Based on the morphology of conidia and conidiophores, the causal agent of powdery mildew was identified as *S. fuliginea* for 234 of the 236 samples of mildewed cucurbits examined. In this survey, watermelon was found free of powdery mildew, with the exception of one site in Western Sudan, where mild symptoms were detected. *Erysiphe cichoracearum* was found on both samples taken from that site. *Leveillula taurica* was never detected. Cleistothecia were not observed on any of the samples.

In the three field trials, *S. fuliginea* was the only species identified. Among the differential melon lines, Iran H, Védrantais, and Nantais oblong were diseased in the summer trial in Gezira. In the winter trial, symptoms were found on PMR45 in addition to the three lines listed above (Table 2). Based on the known interaction phenotypes of the differential lines (Table 1), race 1 of *S. fuliginea* was present on the experimental site in the summer and race 2 Europe was present during the following winter. Symptoms were found only on Iran H in the Gash Delta, leading us to conclude that these strains of *S. fuliginea* were race 0.

The virulence tests conducted on single-spore isolates under controlled conditions indicated that both races 1 and 2 Europe of *S. fuliginea* were present on melon in the winter trial in Gezira (Table 3). Isolates from the squash plants sampled from fields adjacent to the Gezira experimental site were also identified as race 2 Europe on melon.

The 29 local cultigens tested in June in Gezira were all heavily diseased, suggesting that they are susceptible to at least race 1 of *S. fuliginea*.

Table 2. Observed reactions of differential melon genotypes to natural inocula of powdery mildew in three field trials in Sudan in 1993–1994

	Gezira trials		Gash Delta trial
Melon line	June sowing	November sowing	September sowing
Iran H	S[a]	S	S
Védrantais	S	S	R
PMR 45	R	S	R
PMR 5	R	R	R
Nantais oblong	S	S	R
Edisto 47	R	R	R

[a]S = susceptible; R = resistant to powdery mildew.

DISCUSSION

The results of the present study clearly identify *S. fuliginea* as the most prevalent cause of powdery mildew on cucurbits in Sudan. *Ersiphe cichoracearum* was recovered from watermelon at a single sampling site in the study. To our knowledge, this is the first report that clearly establishes *E. cichoracearum* on cucurbits in Sudan, although this species has been observed in Libya, where it was restricted to greenhouse cucumbers (5). While watermelon is generally considered resistant to both *S. fuliginea* and *E. cichoracearum* (3), mild symptoms have sometimes been observed in the field (6,10) and following artificial inoculations in controlled conditions (3). One watermelon accession, PI 269677, has also been reported in the United States as very sensitive to powdery mildew (9). In a later study, PI 269677 was found to be susceptible to *S. fuliginea* races 0, 1, and 2, and *E. cichoracearum* races 0 and 1 (3). Additional work will be required to determine whether the observed symptoms in Sudan resulted from the presence of an unusually aggressive strain of *E. cichoracearum*, a particularly susceptible line of watermelon, or unusual environmental conditions. *Leveillula taurica* was never observed on cucurbits in our survey, although it was often present on tomato and pepper plants in plots adjacent to sampling sites. It has been reported in Libya on greenhouse-grown cucumbers, squash, and pumpkin (5).

Only race 1 of *S. fuliginea* was observed in the summer field trial conducted in Gezira, while in the winter trial both races 1 and 2 were present (Tables 2 and 3). Although virulence tests in controlled conditions were only performed on a few isolates (Table 3), they provide a rough estimate of the proportion of race 2 isolates in the winter trial: 86% (6 out of 7). Considering the high inoculum pressure at the experiment sites and the high level of severity observed in diseased plots, it seems unlikely that failure to detect symptoms on a given melon line could have resulted from disease escape. This suggests that race 2 of *S. fuliginea* was probably absent from the summer experiment site in Gezira, and that a drastic shift in prevalence must have occurred from the summer to the winter of 1993. However, the geographic scale of this shift may have been limited, as only race 0 was detected in the late autumn trial in the Gash Delta, 600 km from Gezira. In view of the agronomic importance of monitoring races of powdery mildew (11,13), further work is needed to gain a better understanding and evaluate the influence of environmental parameters on the chronological and geographic scale of such shifts in race prevalence.

All cultigens of melon tested were susceptible to race 1 of *S. fuliginea* in Gezira. Therefore, they are likely to be susceptible to race 2 also (7). The observed prevalence of these races in Sudan suggests that strains of both races should be included in breeding efforts aimed at improving resistance to powdery mildew in melon varieties adapted to Sudanese growing conditions.

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Table 3. Identification of single-spore isolates of *Sphaerotheca fuliginea* to races based on virulence against differential melon lines[a]

	Sphaerotheca fuliginea isolate						
Melon line	M1	M2	M3	M4	S1	S2	S3
Iran H	9.0[b] S[c]	9.0 S	9.0 S	6.0 S	9.0 S	9.0 S	9.0 S
Védrantais	9.0 S	9.0 S	9.0 S	6.3 S	9.0 S	9.0 S	9.0 S
PMR 45	5.8 S	5.3 S	5.6 S	0.0 R	3.3 S	6.8 S	6.0 S
PMR 5	0.0 R	0.0 R	0.0 R	0.0 R	0.0 R	0.0 R	0.0 R
Edisto 47	0.0 R	0.0 R	0.0 R	0.0 R	0.0 R	0.0 R	0.0 R
Race identification	2	2	2	1	2	2	2

[a]Strains were isolated from melon (M1-M4) and squash (S1-S3) in the winter of 1993 on the experimental site of Gezira.
[b]Average of ratings for 8 whole leaf disks on a scale from 0 (no symptoms) to 9 (heavy sporulation).
[c]S = susceptible; R = resistant (ratings < 3).

for cucurbit powdery mildews (*Sphaerotheca fuliginea* (Schlecht. ex Fr.) Poll. and *Erysiphe cichoracearum* DC ex Merat). Pages 75-76 in: Cucurbitaceae 88, Proc. Eucarpia Meet. Cucurb. Genet. Breed. G. Risser and M. Pitrat, eds. I.N.R.A. Serv. Ind. Agric. Aliment., Paris.

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In the article "Host Range Expansion of the Alfalfa Rust Pathogen" by D. Z. Skinner and D. L. Stuteville on pages 456-460, Figures 1 and 2 and their captions should appear as follows:

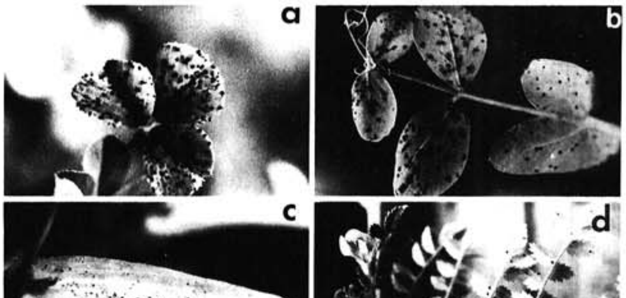

Fig. 1. Examples of uredinia production by isolate KR1-1 of *Uromyces striatus* on **(A)** *Medicago sativa,* **(B)** *Pisum sativum,* **(C)** *Lathyrus aphaca,* and **(D)** *Cicer anatolicum.*

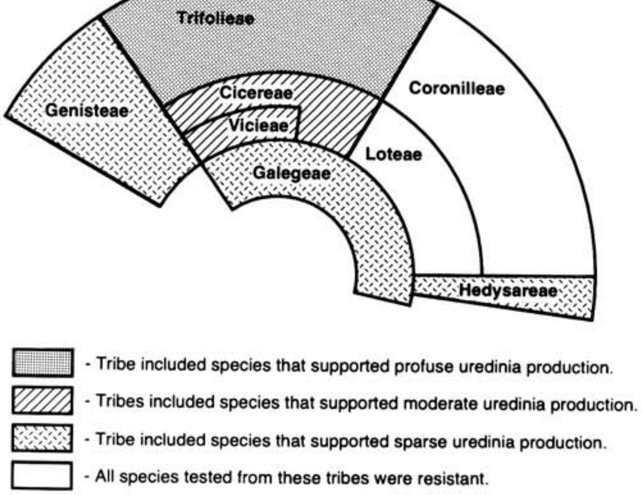

Fig. 2. Leguminous plant tribes including species that supported profuse, moderate, or sparse uredinia production by *Uromyces striatus* superimposed on a representation of the suggested phylogenetic relationships of the tribes (after Polhill, 1981, pages 191–208). Concentric lines indicate grades of evolutionary advancement; radial lines demarcate series of related tribes.